An overview to Software Architecture in Intrusion Detection System

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Abstract. Network intrusion detection systems provide proactive defense against security threats by detecting and blocking attack-related traffic. This task can be highly complex, and therefore, software-based network intrusion detection systems have difficulty in handling high speed links. This paper reviews of many type of software architecture in intrusion detection systems and describes the design and implementation of a high-performance network intrusion detection system that combines the use of software-based network intrusion detection sensors and a network processor board. The network processor acts as a customized load balancing splitter that cooperates with a set of modified content-based network intrusion detection sensors in processing network traffic.

Keywords: Intrusion Detection systems, Software Architecture, IDS, Network

1. Introduction

In the last few years, Internet has experienced an explosive growth and growth. Along with the wide proliferation of new services, the number and impact of security attacks have been continuously increasing. Indeed, the knowledge required to carry out an attack has been decreasing, since software tools for this aim are largely available on Web sites all over the world [1, 2].

Intrusion detection has been an active field of research for about two decades, starting in 1980 with the publication of John Anderson’s Computer Security Threat Monitoring and Surveillance, which was one of the earliest papers in the field. Dorothy Denning’s seminal paper, “An Intrusion Detection Model,” published in 1987, provided a methodological framework that inspired many researchers and laid the groundwork for commercial products.

Still, despite substantial research and commercial investments, ID technology is immature and its effectiveness is limited. Within its limitations, it is useful as one portion of a defensive posture, but should not be relied upon as a sole means of protection. Many recent media reports point to the need for comprehensive protection of which ID is a crucial part.

Recent advances in encryption, public key exchange, digital signatures, and the development of related standards have set a foundation for network security. However, network security goes beyond, because it must include security of computer systems and networks, at all levels, top to bottom.

To this aim, the use of an Intrusion Detection System (IDS) is of primary importance to reveal ongoing intrusions in a network or in a system. An IDS [3] is a software/hardware tool designed to reveal an intrusion while it is in act, or after it has occurred. IDSs are usually classified on the basis of two
distinct aspects: the scope (Network IDSs vs. Host IDSs) and the detection technique (Misuse or Signature based IDSs vs. Anomaly based IDSs) [4, 5]. State of the art in the field of intrusion detection is mainly represented by misuse based IDSs [6]. Considering that most attacks are realized with known tools, downloaded from the Internet, a signature based IDS could seem a good solution.

They rarely used automated tools and exploit scripts. Today, anyone can attack Internet sites using readily available intrusion tools and exploit scripts that capitalize on widely known vulnerabilities. Figure 2, taken from earlier work of SEI [33], which describes the attacks, illustrates the relationship between the relative sophistications of attacks and attackers from the 1980s to the 2000s.

In this paper we review of many type of software architecture in intrusion detection systems and describe the design and implementation of a high-performance network intrusion detection system that combines the use of software-based network intrusion detection sensors and a network processor board. Given a training dataset, the IDS is able to build a model of the normal behavior of the network, which will be used, during the running of the system, to classify network activity either as normal or anomalous. Mainly for this aspect, the system is named Self-Learning Intrusion Detection System (SLIDS). The paper is organized as follows: in section 2 we describe the architecture and the functionalities of SLIDS. Section

2. Software Architecture

In any model of IDSs we need to know what is software architecture and how can we define it, then in this section we want to review this requirement.

Software architecture has emerged as an important sub-discipline of software engineering, particularly in the realm of large system development. While there is no universal definition of software architecture, there is no shortage of them, either. The following are a few of the most cited ones:

• Bass, Clements, and Kazman, 1998: The software architecture of a program or computing system is the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the relationships among them. By “externally visible” properties, we
are referring to those assumptions other components can make of a component, such as its provided services, performance characteristics, fault handling, shared resource usage, and so on[9].

- Garlan and Perry, 1995: The structure of the components of a program/system, their interrelationships, and principles and guidelines governing their design and evolution over time [10].

- Garlan and Shaw, 1993: ...beyond the algorithms and data structures of the computation; designing

To elaborate, software architecture can play an important role in at least six aspects of software development [14].

1. Understanding: Software architecture simplifies our ability to comprehend large systems by presenting them at a level of abstraction at which a system’s design can be easily understood [15,16,17]. Moreover, at its best, architectural description exposes the high level constraints on system design, as well as the rationale for specific architectural choices.

2. Reuse: Architectural design can support reuse in several ways. Current work on reuse generally focuses on component libraries. Architectural design supports, in addition, both reuse of large components (or subsystems) and also frameworks into which components can be integrated. Such reusable frameworks may be domain-specific software architectural styles [18, 19], component integration standards [19], and architectural design patterns [20].

3. Construction: An architectural description provides a partial blueprint for development by indicating the major software components and dependencies between them. For example, a layered view of architecture typically documents abstraction boundaries between parts of a system’s implementation, clearly identifying the major internal system interfaces, and constraining what parts of a system may rely on services provided by other parts [15].

4. Evolution: Software architecture can expose the dimensions along which a system is expected to evolve. By making explicit the “load-bearing walls” of a system, system maintainers can better understand the ramifications of changes, and thereby more accurately estimate costs of modifications. Moreover, architectural descriptions separate concerns about the functionality of a component from the ways in which that component is connected to (interacts with) other components, by clearly distinguishing between components and mechanisms that allow them to interact. This separation permits one to more easily change connection mechanisms to handle evolving concerns about performance and reuse.

5. Analysis: Architectural descriptions provide new opportunities for analysis, including system consistency checking [11, 21], conformance to constraints imposed by an architectural style [13], conformance to quality attributes [22], dependence analysis, and domain-specific analyses for architectures built in specific styles [23, 24, 25].

6. Management: Experience has shown that successful projects view achievement of viable software architecture as a key milestone in an industrial software development process. Critical evaluation of architecture typically leads to a much clearer understanding of requirements, implementation strategies, and potential risks [26].

7. Communication: An architectural description often serves as a vehicle for communication among stakeholders.
3. Intrusion Detection Systems

System objective is to design a behavior based system to detect intruders in a computer network. Operation of the system is divided into three phases: Input Data Collection and Preprocessing, Training and Detection. In preprocessing phase, network traffic is collected and processed for use as input to the system. In the training phase, this system gathers knowledge about the normal behavior of the network users from the preprocessed input data, and store the acquired knowledge. In the detection phase, the system detects attacks based on the knowledge which is achieved during the training phase, and notify the system administrator.

The main task is to generalize and classify user behavior and detect intruders from this classification. This task may be carried out using various approaches like experts systems, rule based induction, artificial neural network approaches etc.

The system overview is given in Figure 2.

We faced a number of design challenges in constructing IDS with respect to performance, flexibility and scalability:

a. Performance:

The primary metric of interest in the design of a IDS is throughput. That is, to be able to operate at network speeds of at least 1 Gbit/s without packet losses, so as to detect any attempted attack. Therefore, the system must be capable of analyzing all the incoming traffic under the most stringent conditions. Network intrusion detection systems (IDSes) based on commodity PCs are able to monitor at speeds much lower than 1Gbit/s [27, 28].

This necessitates the use of a distributed design with several intrusion detection sensors operating in parallel and supported by a load balancing traffic splitter [29, 30]. At the same time, we want to minimize cost and use as few resources as possible.

a. Flexibility and Scalability:

An IDS needs to be flexible and scalable, both for scaling up to higher link speeds and more expensive detection functions, as well as for updating the detection heuristics. If the protection of a faster link or a more fine-grained detection is required, it would be desirable to reuse as much as possible of the existing hardware. However, it is remarkable that almost all IDS providers ignore this dimension. Furthermore, a prerequisite of flexibility is simplicity as extending a complex system may be hard and error-prone. It is therefore desirable for the hard-to-program elements of our system to be as generic as possible.
4. Cluster software architecture for IDS

The Cluster Head Module (CHM) is other model proposed and published in [31]. The CHM runs on each cluster-head node, and is responsible for the management of the cluster-member nodes in the cluster. CHM is also responsible for initiating cooperative intrusion detection and response action upon receiving a request from a cluster-member node.

The CHM is divided into six modules:

I. Cluster management module
II. Network information module
III. Mobile agent management module
IV. Global intrusion information module
V. Collaborative intrusion detection module
VI. Global intrusion response module. The interrelationships among the modules are depicted in Figure 3.

The modules interact with each other via suitable messages in order to collect, store, process, and analyze the data. The functionalities of these modules are described below.
The cluster management module manages the cluster by performing the functions such as:

I. Registration of newly joined nodes
II. Supervision of elections in the cluster
III. Communication with other nodes in the cluster for cooperative intrusion detection. This module consists of three sub-modules:
   a. Cluster-member registration sub module
   b. Cluster-head election sub-module
   c. Cluster member communication sub-module. In the rest of this subsection, the functionalities of these modules are described in the rest of this Section.

The cluster-member registration sub-module is responsible for managing all the member nodes in its cluster.

Every node that comes within the radio range of a cluster head and becomes a part of the cluster will have to register itself to the cluster-head. The cluster-head election sub module is responsible for managing the elections and successfully forwarding all cluster-related information to the newly elected cluster-head. The cluster-member communication sub-module [32] is used for the intra-cluster communication between the cluster-head and the cluster members.

This may be used for cluster-head elections, global intrusion detection, and coordination among the mobile agents, local intrusion update, and global intrusion response actions.

The network information module keeps track of network wide information such as information regarding the cluster head nodes of the neighboring clusters. It is the responsibility of a cluster-head to inform the neighboring cluster-heads about any network-wide intrusion response action, which is further propagated to the cluster members of the neighboring clusters [31].

5. Conclusion

In this paper, we have presented review of software architecture for intrusion detection systems as agent base and cluster-based intrusion detection architecture. The clustering of the network nodes makes
message communication efficient and intrusion detection system robust. Local detection allows for detection of attacks, which are localized to a node or a cluster, whereas global detection involves collaboration among the nodes in different clusters.

References


